Internal roosting location is associated with differential use of the outdoor range by free-range laying hens

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Abstract

1. In commercial free-range systems for laying hens popholes to the outdoor range are often installed on one side of the house only. In multi-tier systems, it is possible that some individuals fail to access the range due to internal barriers to movement.
2. Five commercial multi-tier flocks from different units were studied. For each flock, two different colour markers were used to distinguish 200 birds roosting near the popholes (NP-Roost) and 200 birds roosting far from the popholes (FP-Roost) at night. The following day, counts of marked birds on the range and inside the house were performed.
3. Significantly more NP-Roost birds were observed in all areas of the outdoor range than FP-Roost birds the next day. Distance of FP area from the popholes was very strongly positively correlated with effect size in the adjacent range area.
4. Additionally, in the indoor area far from the popholes (FP) more FP-Roost birds were observed the next day than NP-Roost birds. In the indoor area near to the popholes (NP) more NP-Roost birds were observed the next day than FP-Roost birds.
5. These results suggest that roosting location is associated with differential range use when popholes are only available on one side of the shed as birds that roosted far from the popholes used the range less.

Keywords

Welfare, Behaviour, Laying hens, Multi-tier, Aviary, Range use, Free range

1. Introduction

Loose-housing systems for laying hens allow birds to move around the house freely, accessing various resources such as litter, feed, water, nestboxes, and in free-range systems, the outdoor range. In both single and multi-tier (also known as aviary) systems the feed, water and nestboxes are on one or more elevated tiers with litter and range access available at ground level. Questions have been raised about the ability of birds to move throughout these systems, particularly where multiple potential barriers to movement are present (Stratmann *et al.*, 2015; Ali *et al.*, 2016). In all loose-housing systems birds have to negotiate level changes (from tier to ground, or between tiers) to access resources, and some housing configurations require birds to negotiate level changes just to move from one side of the house to the other. Research has shown behavioural signs of hesitation and difficulty negotiating the key level change between the slats (or first tier) and the litter (Pettersson *et al.*, 2017) and ramps between all levels of a multi-tier system were found to reduce falls and collisions (Stratmann *et al.*, 2015).

An additional potential barrier to free movement can arise if hens crowd together, creating increased stocking densities in certain areas, particularly around resources (Collins *et al.*, 2011; Lentfer *et al.*, 2013) and walls (Newberry and Hall, 1990). Higher stocking densities have been associated with reduced bird movement (Appleby *et al.*, 1989; Carmichael *et al.*, 1999).

At night, hens choose to roost on high perches when available (Olsson and Keeling, 2000) and in multi-tier systems will fill the higher tiers (Odén *et al.*, 2002; Ali *et al.*, 2016). A study of groups (mean group size of 588 birds) housed in a multi-tier system found that birds that roosted in end areas of the pen stayed within that area during the following days more than would be expected by chance and often roosted in the same place in the following night (Odén *et al.*, 2000). In a few small experimental studies hens have shown individual differences in location use within commercial-style aviaries (Freire *et al.*, 2003; Campbell *et al.*, 2016) although it is not clear whether this was due to capability of moving around, individual preference or feather pecking by other birds. Home ranges and ‘activity centres’

can be calculated for individual laying hens within commercial units (Leone and Estevez, 2008; Rodriguez-Aurrekoetxea and Estevez, 2016) suggesting that birds tend to use certain areas more often. Interestingly birds that range more were found to have larger home ranges and activity centres (Rodriguez-Aurrekoetxea and Estevez, 2016), possibly because of the increased opportunity to travel further in the outdoor area. Inside the house having a small home range may not be an issue as all key resources such as feed, water, nestboxes and litter are usually well distributed throughout. However, range access may prove difficult in this case.

The proportion of birds using the range at a given time is often low (Pettersson *et al.,* 2016a) and research using RFID tracking technology on commercial farms has found that some birds do not appear to use the popholes, and therefore the range, at all (8%: Richards *et al.,* 2011; 29.5%: Gebhardt-Henrich *et al.,* 2014). Some consumers believe free-range hens to be happier and healthier than in other systems and access to the range to be the most important factor for welfare (Pettersson *et al.,* 2016b). Actual levels of range use in commercial systems may therefore not meet consumer expectation. When popholes are available only on one long side of the house, some birds will have to travel many metres to access the range and in multi-tier systems a view of the popholes is blocked by the tiers themselves for birds in most areas of the house. It is possible that hens may not even be aware of the range area if they cannot see the popholes. If this was the case we would expect birds that started off the day in an area where popholes were visible to be more likely to use the range than those that have to travel far to access that area.

The two aims of this study were to test our predictions that (i) birds that roost near to the popholes will be more likely to use the range area the next day than those that roost far away from the popholes and (ii) birds will stay near to their night-time roosting location the next day.

2. Materials and Methods

The study used five commercial free-range multi-tier flocks with flock sizes of approximately 16,000 birds. Two flocks were on the same farm but housed in separate buildings (see the table for flock and house information). All flocks had pre-existing colony divisions within the house separating the flock into four colonies of approximately 4000 birds and popholes were fitted to one long side of the house only, evenly spaced. Birds were not able to access other colonies areas inside the house although they could when out on the range in all flocks except for flock 1 which had physical colony divisions on the range. Fig 1 shows the layout of multi-tier stacks within flocks 2-5. Flock 1 was slightly different as the shed was divided into colonies in a 2x2 design. Nonetheless, the layout of stacks within the studied colony remains the same as the other flocks. Although some houses closed the area under the tiers off during the night, these were not closed off for flocks 1,3,4 and 5 during the day. This meant that birds could walk along the litter from one side of the house to the other. In flock 2 the area under the tiers was closed off for the first of the three observations as the producer did not choose to open up this area until 11am. All flocks were allowed out onto the range at 9 am. All flocks had 16-17 hours light.

The study involved a 2-day visit to each flock when the birds were 41-47 weeks of age. These visits took place between late-August and mid-November 2016 and weather conditions were similar for all flocks. House design and dimensions were recorded. Ethical permission was obtained from the University of Bristol ethical committee prior to starting the project.

--- SUGGESTED LOCATION FOR TABLE ---

2.1. Marking birds

In order to establish whether birds used all areas of the house and range, two samples of individual hens were marked during the night of Day 1 (between 9pm and 2am) when the lights were off and birds were roosting. Researchers used red light head torches when in the house to minimise bird disturbance. One colony was selected per flock and 400 birds

(approximately 10% of the colony) were marked. Two distinct areas were established – 'near' the popholes (NP) and 'far' from the popholes (FP) (see fig 1). On the tiers, 200 roosting birds from the NP area were marked green (NP-Roost) and 200 roosting birds from the FP area were marked pink (FP-Roost). Birds were selected evenly across the areas, with the highest tier unable to be sampled due to accessibility. All birds were generally in good condition although any birds with visible problems such as bumblefoot were excluded. Livestock marker crayons (Paintstik®, All-Weather®, USA) in fluorescent green and fluorescent pink were used to colour one entire leg of each bird. The two colours plus another (blue) were tested in a pilot trial and blue was found to be the least visible so was not used. One researcher lifted each bird from its roosting position and held it steady while another researcher marked the leg with the appropriate colour. Each bird was then placed back in the same location, where they remained, with little indication of disturbance. This process took about 30 seconds per bird.

2.2. Observations and counts

Marked birds were counted at three time-points the next day (approximately 90min apart) between 10am and 1pm. Mean temperature, relative humidity and light levels were similar in both NP and FP areas. Indoor counts were performed first at each time point, immediately followed by range counts. Further counts were not performed; in part owing to time constraints but also because the researcher's presence was likely to be disturbing the natural distribution of the birds with every observation. When assessing range use the number of NP-Roost and FP-Roost marked birds were counted in two areas of the range; adjacent and non-adjacent. The adjacent area was divided from the non-adjacent area by visualising a line as a continuation of the internal colony divisions (see fig 1). The observer had experience counting ranging birds and walked methodically through the range areas counting both the total number of birds outside, and those that were marked. Although only flock 1 had physical colony divisions on the range we hypothesised that more marked birds would be seen within the area adjacent to the studied colony popholes, hence dividing the range area

up visually for these counts. It was too difficult to see the legs of birds on the litter area of the house so these birds were not included in the counts. The researcher walked along the edge of the stacks in the NP area of the house, counting all NP-Roost and FP-Roost marked birds visible on the tiers in this section (back of top tier excluded). A head torch was used to clearly see birds further back on the tiers. Not all birds were visible (e.g. within nestboxes and on the back of the top tier) and these were not counted as it was deemed to be too disruptive for the researcher to look in nestboxes or climb the tiers. The same was then repeated for the FP area. It was not possible for the researcher to be blinded to the groups marked but as the count measure is objective it is unlikely that bias occurred.

--- SUGGESTED LOCATION FOR FIGURE 1 ---

2.3. Statistical analysis

The multilevel statistics package MLwiN (Charlton et al. 2017) was used for the statistical analyses to accommodate the doubly repeated measures of measures within observation number, within house. A separate multi-level model was produced for each area where counts were taken – on the range (adjacent and non-adjacent) and in the house (NP and FP). To look for potential differences in the numbers of NP-Roost and FP-Roost birds, the difference between the two counts was calculated (FP-Roost minus NP-Roost) and used as the outcome variable in these models. Differences in observation number was also tested within these models as a fixed effect. The residuals from the models were checked to ensure they met the assumptions of the model. Although the differences between counts were used in the model, mean counts have been reported for clarity.

For observation 1 in flock 2, the area under the litter was blocked off. As this may have had a large effect on the results and did not match the other flocks, this value has been replaced with an estimated value. The estimation was produced by averaging the values for observations 2 and 3.

To check for correlations between distance of FP area from a pophole and size of the effect on range use, the number of FP-Roost birds counted on the range was subtracted from the number of NP-Roost birds counted on the range for each flock. After checking for normality, Pearson correlations were performed.

3. Results

3.1. Use of outdoor range areas

On average across all flocks and observations 7.34% of the whole flock (both marked and unmarked birds) were seen out on the range at a time with low variability (range of means between flocks: 6.03-8.98%, range of means across the three observations: 7.23-7.42). On average, 5.38% (SD=2.60) of marked birds were seen out on the range at a time.

Within the adjacent range area, significantly more NP-Roost birds (mean=16.20, SD=8.10) were counted than FP-Roost birds (5.33, SD=3.14) (parameter estimate: -9.733(SE: 2.553), $p<0.001$). There was no significant effect of observation number. See fig 2a. Within the non-adjacent range area significantly more NP-Roost (11.47, SD=7.67) than FP-Roost birds (4.00, SD=3.60) were also observed (parameter estimate: -6.200(SE: 2.293), $p<0.001$) with no effect of observation number (Fig 2b).

Distance of FP area from the popholes was very strongly positively correlated with effect size ($r=0.988$, $n=5$, $p=0.002$). As this distance increased, the proportion of NP-Roost birds relative to FP-Roost birds, seen on the range also increased. For the non-adjacent area of the range this relationship did not reach significance ($r=0.816$, $n=5$, $p=0.092$).

--- SUGGESTED LOCATION FOR FIGURE 2 ---

3.2. Use of NP and FP areas in the house

Within the FP area of the house significantly more FP-Roost birds (15.86, SD=6.16) were counted than NP-Roost birds (6.93, SD=4.07) (parameter estimate:7.200 (SE:1.865), $p<0.001$) (see Fig 3b). There were significant differences between observations with mean differences between FP-Roost and NP-Roost birds for observations 1-3 at 7.20(SD:2.588), 10.20(SD:5.02) and 3.40(SD:5.77) respectively.

In the NP area of the house significantly more NP-Roost (11.20, SD=4.04) birds than FP-Roost birds (6.80, SD=2.12) were counted (parameter estimate: -3.133 (SE: 0.810), $p<0.001$) (see Fig 3a). There was no effect of observation number.

--- SUGGESTED LOCATION FOR FIGURE 3 ---

4. Discussion

The results suggest that night time roosting location affects the next day's range use by individual birds in free-range flocks. As most marked birds should be found in the adjacent area of the range we expected counts from this area to be the most likely to show any significant effects. The strongest results were seen in the adjacent area with more than twice the number of birds that roosted near the popholes (NP-Roost birds) seen in this outside area than birds that roosted far from the popholes (FP-Roost birds) across all three observations. Significantly more NP birds than FP-Roost birds were also observed in the non-adjacent area, suggesting that this effect of bird roosting location on range use exists even in less accessible areas of the range.

These results suggest that by allowing access to outdoor areas on one side of a laying house only, some of the birds may have limited access to the outside compared with others simply because of their location in the house. The reasons why roosting far away from a pophole reduces the likelihood of using the range cannot be determined from this study, although there are a number of possible explanations. Hens appear to have individual home ranges in

commercial units (Rodriguez-Aurrekoetxea and Estevez, 2016) and this may limit their outdoor range use if a pophole is not available within this home range. It may also be the case that it is important for popholes to be visible for a bird to choose to use the range area. Another possible explanation is that the birds which roost in certain areas of the house may have some other characteristics affecting their use of the range such as weight, or behavioural traits such as fearfulness. However, this remains speculation at the moment and has not been tested. The fact that the difference in numbers of birds from both roosting locations was greater on the range when the distance to travel was greater suggests that the results seen in this study are closely related to the distance of roosting location from available popholes.

Our second objective was to test the prediction that hens stay in the vicinity of their roosting location the next day. This study found that more FP-Roost birds than NP-Roost birds were observed in the FP house area the next day and more NP-Roost than FP-Roost birds were observed in the NP house area. These results suggest that birds tend to stay in the same area as they roosted the night before, with few birds coming from other areas of the house. This is backed up by the results for the range areas, as birds with popholes near to their roosting location (NP-Roost) birds ranged more. If hens are reluctant to travel far from their roosting location the FP-Roost birds are less likely to make it to a pophole and out onto the range. There was an effect of observation number in the FP area. Although the direction of the effect remained consistent across all observations for more FP-Roost birds, the size of this effect increased for the second observation and then decreased for the final observation suggesting that the numbers of birds had begun to even out by observation three. However, this preliminary study looked only at a few hours following pophole opening and so information on bird movement over a longer period is essential to establish if this effect is true.

This study was designed to provide the first evidence of a problem often discussed by producers and scientists but lacking in scientific evidence – that some laying hens do not

access certain resources, particularly the outdoor range where popholes are limited. Very little work has studied the effect of bird roosting location on movement in commercial flocks although some data is available (Odén *et al.,* 2000) and this is the first to look at the effect on multiple free-range commercial units.

As this was a preliminary study, further measures that may have helped to determine the specific reasons behind the results such as measures of individual health and behaviour were not taken but would be a valuable avenue for further investigation. Additionally, this study only looked at one day and did not cover whether birds return to the same area to roost. This was mostly due to limitations of the marking method as it was not designed to last longer than a day or two. The results of this study did not find that marked bird numbers in each location were affected by the time observed in most areas (within the scope of the study) but it would be useful to know if this is a short or long-term effect. Due to practical and safety reasons, it was not possible to mark birds from the highest tier. It is possible that this may have influenced the results as birds that perch on the highest tier may have different behavioural traits than the rest of the flock.

The marking method trialled in this study was found to be relatively successful. It was easy to mark birds with two people and the colours chosen were very distinct. No negative effects such as feather pecking by conspecifics were seen by the researchers during the study or reported by the producers, likely because the legs of the birds were marked rather than the plumage. While leg marks were easy to see on tiers, they were difficult to spot on crowded ground areas such as the litter. For the purpose of this study this was not considered a major issue as information about bird movement and location could still be collected from other birds. The method may not be appropriate however if litter use is of particular interest. On average, a slightly lower percentage of marked birds were seen ranging than the total percentage of marked and unmarked birds ranging. As this was only a difference of approximately 2% the ability of the researcher to identify marked birds on the range was

adequate. The method appears to be useful for marking groups of birds (rather than individuals) on a short-term basis in commercial flocks.

To conclude, this study provides the first evidence that some laying hens within large free-range commercial units may have limited access to the outdoor range area if popholes are provided on one side of the house only. Efforts to improve the design of free-range units are often focused on the range area or pophole size and number. This research has highlighted a need to consider the placement of popholes in addition to these factors in order to provide access to all resources for all individuals in a commercial flock.

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References

ALI, A., CAMPBELL, D., KARCHER, D. & SIEGFORD, J. (2016). Influence of genetic strain and access to litter on spatial distribution of 4 strains of laying hens in an aviary system. *Poultry Science,* **95**: 2489-2502.

APPLEBY, M., HUGHES, B. & HOGARTH, G. (1989) Behaviour of laying hens in a deep litter house. *British Poultry Science,* **30**: 545-553.

CAMPBELL, D., MAKAGON, M., SWANSON, J. & SIEGFORD, J. (2016) Laying hen movement in a commercial aviary: Enclosure to floor and back again. *Poultry Science,* **95**: 176-187.

CARMICHAEL, N.L., WALKER, A.W. & HUGHES, B.O. (1999) Laying hens in large necks in a perchery system: influence of stocking density on location, use of resources and behaviour. *British Poultry Science,* **40**: 165-176.

CHARLTON, C., RASBASH, J., BROWNE, W.J., HEALY, M. & CAMERON, B. (2017) MLwiN Version 3.00. Centre for Multilevel Modelling, University of Bristol.

COLLINS, L.M., ASHER, L., PFEIFFER, D.U., BROWNE, W.J. & NICOL, C.J. (2011) Clustering and synchrony in laying hens: The effect of environmental resources on social dynamics. *Applied Animal Behaviour Science,* **129**: 43-53.

FREIRE, R., WILKINS, L., SHORT, F. & NICOL, C. (2003) Behaviour and welfare of individual laying hens in a non-cage system. *British Poultry Science,* **44**: 22-29.

GEBHARDT-HENRICH, S.G., TOSCANO, M.J. & FROEHLICH, E.K.F. (2014) Use of outdoor ranges by laying hens in different sized flocks. *Applied Animal Behaviour Science,* **155**: 74-81.

LENTFER, T., GEBHARDT-HENRICH, S., FRÖHLICH, E. & VON BORELL, E. (2013) Nest use is influenced by the positions of nests and drinkers in aviaries. *Poultry Science,* **92**: 1433-1442.

LEONE, E.H. & ESTEVEZ, I. (2008) Use of space in the domestic fowl: separating the effects of enclosure size, group size and density. *Animal Behaviour*, **76**: 1673-1682.

NEWBERRY, R. & HALL, J. (1990) Use of pen space by broiler chickens: effects of age and pen size. *Applied Animal Behaviour Science,* **25**: 125-136.

ODÉN, K., KEELING, L. & ALGERS, B. (2002) Behaviour of laying hens in two types of aviary systems on 25 commercial farms in Sweden. *British Poultry Science,* **43**: 169-181.

ODÉN, K., VESTERGAARD, K. & ALGERS, B. (2000) Space use and agonistic behaviour in relation to sex composition in large flocks of laying hens. *Applied Animal Behaviour Science,* **67**: 307-320.

OLSSON, I.A.S. & KEELING, L.J. (2000) Night-time roosting in laying hens and the effect of thwarting access to perches. *Applied Animal Behaviour Science*, **68**: 243-256.

PETTERSSON, I., FREIRE, R. & NICOL, C. (2016a) Factors affecting ranging behaviour in commercial free-range hens. *World's Poultry Science Journal*, **72**: 137-150

PETTERSSON, I.C., WEEKS, C.A. & NICOL, C.J. (2016b) Consumer perceptions of free-range laying hen welfare. *British Food Journal*, **118:** 1999-2013.

PETTERSSON, I.C., WEEKS, C.A. & NICOL, C.J. (2017) The effect of ramp provision on the accessibility of the litter in single and multi-tier laying hen housing. *Applied Animal Behaviour Science*, **186**: 35-40.

RICHARDS, G.J., WILKINS, L.J., KNOWLES, T.G., BOOTH, F., TOSCANO, M.J., NICOL, C.J. & BROWN, S.N. (2011) Continuous monitoring of pop hole usage by commercially housed free-range hens throughout the production cycle. *Veterinary Record*, **169**: 338.

RODRIGUEZ-AURREKOETXEA, A. & ESTEVEZ, I. (2016) Use of space and its impact on the welfare of laying hens in a commercial free-range system. *Poultry Science*, **95**: 2503-2513.

STRATMANN, A., FRÖHLICH, E.K.F., GEBHARDT-HENRICH, S.G., HARLANDER-MATAUSCHEK, A., WÜRBEL, H. & TOSCANO, M.J. (2015) Modification of aviary design reduces incidence of falls, collisions and keel bone damage in laying hens. *Applied Animal Behaviour Science*, **165**: 112-123.

348 Table: Flock information

Flock number	Flock size	Genotype	System	Number of tiers	Light schedule	Feeds per day	Number of popholes (studied colony)	Pophole size (height x width) (cm)	Distance of FP area from popholes (m)	Distance of NP area from popholes (m)	No. of tier stacks to cross (from FP to NP)	Bird age at visit (weeks)
1	15837	Lohmann Brown	Jansen	3	6:00-22:00	5	6	46 x 230	9.65	4	2	42
2	16032	Lohmann Brown	Dutchman Natura Twin	2	5:15-21:40	5	5	50 x 272	12.10	3.7	2	41
3	16032	Bovan Brown	Dutchman Natura Twin	2	6:00-21:00	5	5	49 x 268	12.10	3.1	2	47
4	16032	Bovan Brown	Dutchman Natura Twin	2	6:00-21:00	5	5	50 x 270	12.80	3.35	2	47

5	16032	Lohmann Brown	Vencomatic Veranda Aviary	2	5:00-22:00	6	6	51 x 205	9.80	2.6	2	44

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351 Figure 1: Diagram of an example house layout with observation areas marked.

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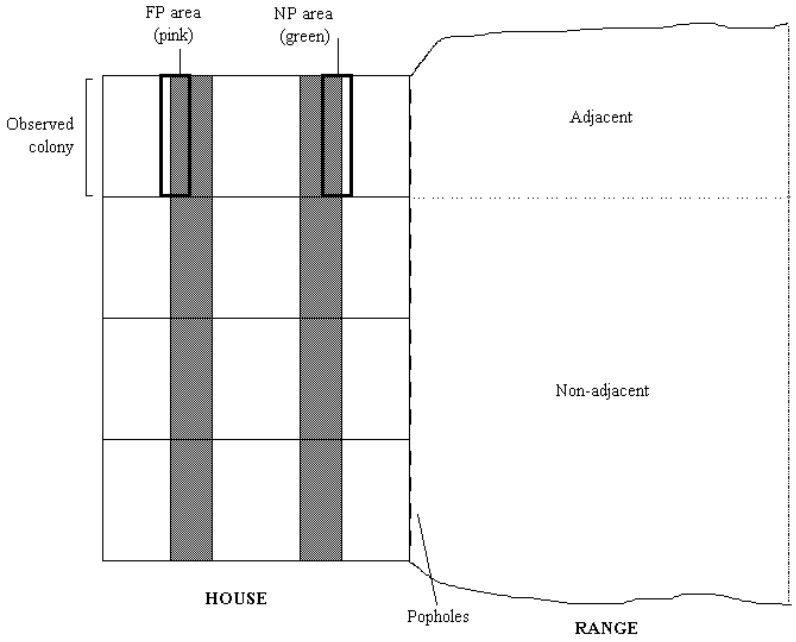

354 Figure 2: Mean counts of marked birds in the two range locations across the three

355 observations (error bars: +/- 2SE).

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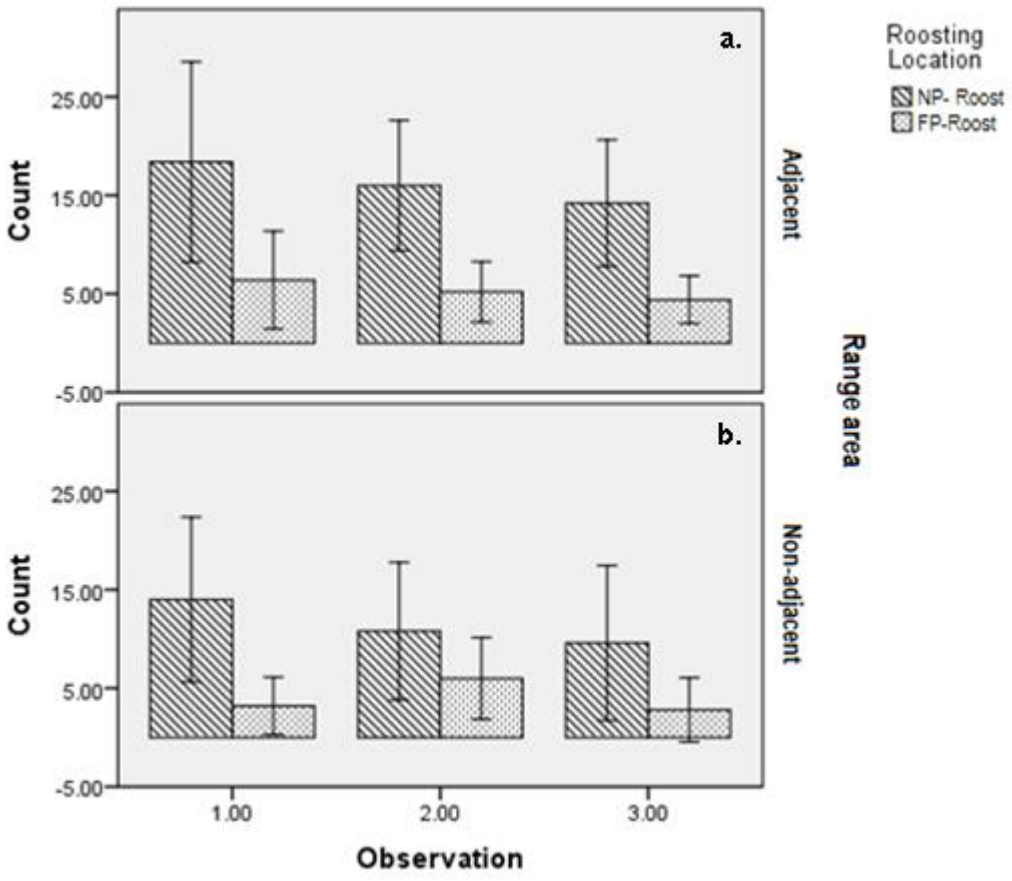

Figure 3: Mean counts of marked birds in the two indoor locations across the three observations (error bars: +/- 2SE).